EGU22-4458, updated on 06 Dec 2022
https://doi.org/10.5194/egusphere-egu22-4458
EGU General Assembly 2022

Addressing effective real-time flood forecasting for upstream artificial reservoirs through predictive uncertainty

Silvia Barbetta[1], Bhabagrahi Sahoo[2], Bianca Bonaccorsi[1], Tommaso Moramarco[1], Trushnamayee Nanda[3], Chandranath Chatterjee[3], and Ezio Todini[4]
[1]Research Institute for Geo-hydrological Protection, CNR, Perugia, Italy
[2]School of Water Resources, Indian Institute of Technology Kharagpur, Kharagpur-721302, India
[3]Agricultural and Food Engineering Dept., Indian Institute of Technology Kharagpur, Kharagpur-721302, India
[4]Italian Hydrological Society, Piazza di Porta San Donato, 40126, Bologna, Italy

The impact of flood events is usually approached through structural measures, such as riverbanks and dams able to mitigating, although not fully eliminating flooding risk. Therefore, complementary non-structural measures, mainly real-time Flood Forecasting and Warning Systems (FFWSs), usually combined with operational decision support systems, must be developed to improve the population safety and resilience. Flood forecasting models, essential components of FFWSs, provide deterministic forecasts of discharge or water levels at critical sections on forecast horizons to support the decision-makers activities. Unfortunately, under the uncertainty of future events, predictions must be probabilistic, to be effective and to guarantee the required robustness to the decision makers *(Todini, 2017).*

Many studies are available in the literature on generating probabilistic forecasting starting from a deterministic forecast and considering the error distribution. Alternatively, the introduction of the Hydrological Uncertainty Processor (*Krzysztofowicz, 1999*) has posed the basis for the estimation of the predictive uncertainty, PU, that is the probability of occurrence of a future value conditional on all the available information, usually provided by forecasting models.

In this context, for estimating the PU, Todini (*2008*) proposed the Model Conditional Processor (MCP) which allows for the analytical treatment of the multivariate probability densities after converting both observations and model predictions into the Normal space. Afterwards, MCP was extended to the multi-model approach (*Barbetta et al., 2017*) enabling a decision based on “multiple forecasts” of different deterministic models at the same time.

With the aim to shed light on the benefits of using PU, the multi-model MCP is applied to discharge forecasts at sites along Indian rivers. Specifically, a data-driven model, i.e. a novel Wavelet-based Non-linear AutoRegressive with eXogenous inputs (WNARX) model and the grid-based semi-distributed VIC hydrological model are used to this end. The future estimates of the river discharge coming into artificial reservoirs, provided by VIC and WNARX models (*Nanda et al., 2019*) at the same time, are used to feed simultaneously the MCP; thus, showing the benefits in terms of improved effectiveness of the future prediction. The analysis is performed for the Hirahud dam

along the Manhanadi River: the results indicate that the methodology could be able to provide effective probabilistic real-time inflow forecasting to be used during significant floods as an appropriate support for the artificial reservoir management.

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